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# BOOBY NESTING ON RAINE ISLAND, GREAT BARRIER REEF

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Collecting reliable field data on breeding populations of booby species on Raine Island for temporal comparison is challenging. This trial's aim was to establish baseline data on nest census estimates in December 1998 to serve as the foundation for continued monitoring. Based on censuses, estimates of numbers of 3 700 Brown, 700 Masked, and 330 Red-footed Booby nests were established. Egg predation by seagulls in December 2000, however, prevented the first replication of the study thus exposing the limitations of the method.

## INTRODUCTION

Raine Island (144°01'E, 11°37'S), a 28 hectare coral cay that consists of a vegetated ridge surrounding a bare central depression, previously mined for phosphorous, is located approximately 100 kilometres ENE of Cape Grenville, northern Queensland. The island supports breeding colonies of three Booby species: Brown *Sula leucogaster*; Masked *Sula dactylatra*; and Red-footed *Sula sula*.

Brown Booby nests on Raine Island are distinguishable from those of the Masked Booby by the 'loosely assembled' twigs gathered in and around the nest, whereas Maked Booby nests have a small collection of pebbles or coral rubble in the centre with a similar collection surrounding the outer perimeter of the nest (Marchant and Higgins 1990). Although few Masked Boobies nest in the vegetated ridges and on beaches, Warham (1961) suggests that guano mining, that denuded and extended the central depression, may have inadvertently enhanced the preferred habitat for Masked Boobies.

The majority of the bare central depression on Raine Island is occupied by Masked Boobies with Brown Boobies nesting around the edges, extending into all areas of the vegetated ridges. Red-footed Boobies roost and nest, about a foot above ground, on matted vegetation or branches of low shrubs. Except for Moulter Cay, Raine Island supports the only Red-footed Booby colony on the Great Barrier Reef (Taplin and Blaber 1993).

The Raine Island Brown Booby population has been recorded variously as breeding 'in small numbers' in July 1843 (MacGillivray 1846 p. 1478) to 'thousands all over the place' in October 1910 (MacGillivray 1918 p.181), and between 8 000 and 16 000 (no dates provided) (Taplin and Blaber 1993). Without clarification of methods for estimates or counts, little can be surmized concerning population dynamics from the literature; however, Stoddart *et al.* (1981 pp. 23, 26) provided densities for Brown (6.835/100 m$^2$, 2 764 birds) and Masked (1.730/100 m$^2$, 699 birds) Boobies in the whole of the 'guano flats' in November 1973. Reports of the Masked Booby population range from 400 to 500 in February 1959 (Warham 1961) to 1 500–2 500 (no dates provided) (Taplin and Blaber 1993); and for the Red-footed Booby, range from 'a few stragglers' in December 1913 to 300 in February 1959 (Warham 1961).

Because there are few Australian studies detailing Red-footed or Masked Booby breeding numbers or status (Marchant and Higgins 1990) this study attempted, in December 1998, to establish baseline data for continuing breeding population estimates. It was intended to avoid error due to absent birds during the daytime, by estimating breeding populations based on nest census estimates.

## METHODS

Milton *et al.* (in Neil *et al.* 2000 p.13) stated that although the 'quadrat search' for estimates of seabird populations was more practical when time was limited, there was less error in the 'line transect' method. This study was conducted in conjunction with line transect Shearwater data collection (see Dyer 2003).

To establish breeding estimates for the three Booby species, Boobies and their nest contents within ten north/south transects, made up of 4 metre wide × 5 metre long contiguous quadrats, were recorded. Data collection was limited to a couple of hours in the morning and afternoon to avoid the risk of heat stress for birds and researchers alike. During the day, because many birds are absent feeding or leave nests when disturbed by researchers, the nest count was considered to indicate breeding populations more reliably than bird counts.

The ratio method for estimating populations from stratified sample counts (Cochran 1977, see Dyer 2003) was used to estimate all 'cases' (i.e. nests with or without birds, as well as birds without nests). In addition estimates for nests only, and birds only, were established for each of the three Booby species. Data were recorded according to the various habitats previously identified by Jeff Miller (J. Cornelius, pers. comm.) for continuing bird studies (see Dyer 2003). In addition, Pearson's Corelation Coefficient was used to establish any relationship between sample areas and findings, and Chi-squared tests were used to test for any influence according to habitat type or transect location.

Stoddart *et al.* (1981) measured the density of birds in the 'guano flats' using five sample areas. This was then extrapolated to estimate the number of nests for Brown and Masked Boobies in the central depression that, according to Stoddart *et al.*, covered 40 440 square metres. This estimate excluded absent feeding birds; those disturbed by researchers; and birds nesting in the ridge areas. Although the sampling method was not replicated here, a similar mean density measure was established and extrapolated for the central depression, for comparative purposes. Interpretation of comparisons should account for the different timing of data collection. The research reported here was carried out in the early mornings or late afternoons between 4 and 7 December 1998 inclusive, whereas Stoddart, Gibbs, and Hopley's data were collected at midday on 3 November 1973 (Stoddart *et al.* 1981).

## RESULTS

*Brown Booby (Entire Island)*

The breeding stage for Brown Boobies ranged from empty nests, through adults incubating eggs and accompanied and unaccompanied downy chicks, to almost fledged chicks. This diversity complicated analyses so censuses for all cases (aggregating cases with birds and/or nests), for cases involving nests without birds, and for birds without nests, were established.

In 31.9 per cent of cases, Brown Boobies were not obviously on or near a nest (Table 1.1). Unaccompanied chicks constituted the majority of these cases (i.e. 14.5 per cent of all cases). Empty nests constituted 39 per cent of all cases (Table 1.2). The remaining 28.9 per cent of all cases showed signs of breeding. Of these 15.4 per cent (of all cases) represented birds still incubating one or two eggs (Table 1.2). In addition to the habitats analysed, two chicks, one nest, and one nest with an adult, a chick and an egg (i.e. four cases in all) were present in the vicinity of the transect trajectories in the grassy verge that surrounded the vegetated ridge areas.

The census for all habitats combined resulted in estimates of 3 700 (± 7% se) nests, 1 760 (± 9% se) birds, and 5 460 (± 9% se) cases altogether. The latter estimate allowed for absent birds and compared favourably with total counts of Brown Boobies (by the author and others) using a quadrat method for counting, including visible chicks but involving an unknown error factor, of 2 073 mid afternoon on 28 November 1998, and 1 274 mid morning on 10 December 1998. The numbers of cases were positively related to transect areas (Pearson's Correlation Coefficient (df = 8): birds 0.0.914, p = 0.000; nests 0.872, p = 0.001; all cases, 0.926, p = 0.000). No significant relationship was found between Brown Booby nests, Brown Boobies apart from nests, and habitat type ($\chi^2$ = 1.529, df = 4, p = 0.821, n = 335) or transects ($\chi^2$ = 6.551, df = 9, p = 0.684, n = 335).

*Masked Booby (Entire Island)*

The breeding stage of the Masked Booby was similar to that of the Brown Booby in that it encompassed the full range from empty nests to almost fledged chicks. Masked Boobies were counted in those transects that traversed the central depression. In 44.9 per cent of cases birds were not obviously associated with nest (Table 2). Unlike Brown Boobies, lone Masked Booby chicks were the minority in this category, constituting only 9 per cent of all cases. Lone adults or pairs constituted the majority of cases not

TABLE 1.1

Brown Boobies, not in nests, found in December 1998, for habitats on Raine Island: Central Depression; South Section of the Southern Vegetated Ridge (SSVR); North Section of the Southern Vegetated Ridge (NSVR); and Northern Vegetated Ridge (NVR).

| Brown Booby Birds | Habitat | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Depression | | NSVR | | NVR | | SSVR | | TOTAL | |
| (No Nest) | No. | % | No. | % | No. | % | No. | % | No. | % |
| Adult | 14 | 4.2 | 4 | 1.2 | 4 | 1.2 | 1 | 0.3 | 23 | 6.9 |
| Two adults | 1 | 0.3 | 0 | 0.0 | 0 | 0.0 | 1 | 0.3 | 2 | 0.6 |
| Two adults and chick | 1 | 0.3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.3 |
| Adult and chick | 12 | 3.6 | 1 | 0.3 | 4 | 1.2 | 3 | 0.9 | 20 | 6.0 |
| Adult and juvenile | 1 | 0.3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.3 |
| Chick | 27 | 8.2 | 1 | 0.3 | 7 | 2.1 | 13 | 3.9 | 48 | 14.5 |
| Two chicks | 1 | 0.3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.3 |
| Juvenile | 7 | 2.1 | 0 | 0.0 | 1 | 0.3 | 1 | 0.3 | 9 | 2.7 |
| Two juveniles | 0 | 0.0 | 0 | 0.0 | 1 | 0.3 | 0 | 0.0 | 1 | 0.3 |
| Sub-total | 64 | 19.3 | 6 | 1.8 | 17 | 5.1 | 19 | 5.7 | 106 | 31.9 |

TABLE 1.2

Brown Booby nests found in December 1998, for habitats on Raine Island: Central Depression; South Section of the Southern Vegetated Ridge (SSVR); North Section of the Southern Vegetated Ridge (NSVR); and Northern Vegetated Ridge (NVR).

| Brown Bobby | Habitat | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Depression | | NSVR | | NVR | | SSVR | | TOTAL | |
| Nests | No. | % | No. | % | No. | % | No. | % | No. | % |
| Empty | 65 | 19.6 | 15 | 4.5 | 24 | 7.3 | 25 | 7.6 | 129 | 39.0 |
| Adult | 6 | 1.8 | 0 | 0.0 | 2 | 0.6 | 3 | 0.9 | 11 | 3.3 |
| Adult and chick | 13 | 3.9 | 1 | 0.3 | 2 | 0.6 | 5 | 1.5 | 21 | 6.3 |
| Adult, Chick and egg | 4 | 1.2 | 1 | 0.3 | 1 | 0.3 | 0 | 0.0 | 6 | 1.8 |
| Adult and egg | 28 | 8.5 | 1 | 0.3 | 3 | 0.9 | 3 | 0.9 | 35 | 10.6 |
| Adult and two eggs | 8 | 2.4 | 0 | 0.0 | 0 | 0.0 | 1 | 0.3 | 9 | 2.7 |
| Adult, egg and juvenile | 1 | 0.3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.3 |
| Chick | 4 | 1.2 | 0 | 0.0 | 0 | 0.0 | 7 | 2.1 | 11 | 3.3 |
| Egg | 1 | 0.3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.3 |
| Two eggs | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.3 | 1 | 0.3 |
| Sub-total | 130 | 39.2 | 18 | 5.4 | 32 | 9.7 | 45 | 13.6 | 225 | 67.9 |
| Total 1.2 and 1.2 | 194 | 58.60 | 24 | 7.30 | 49 | 14.8 | 64 | 19.3 | 331 | 100.0 |

TABLE 2

Masked Boobies and their nests found in December 1998, for habitats on Raine Island: Central Depression and North Section of the Southern Vegetated Ridge (NSVR).

| | Habitat | | | | | |
|---|---|---|---|---|---|---|
| Masked Booby | Depression | | NSVR | | TOTAL | |
| Birds (no nest) | No. | % | No. | % | No. | % |
| Adult | 12 | 15.4 | 1 | 1.3 | 13 | 16.7 |
| Two Adults | 10 | 12.8 | 0 | 0.0 | 10 | 12.8 |
| Adult and chick | 5 | 6.4 | 0 | 0.0 | 5 | 6.4 |
| Chick | 7 | 9.0 | 0 | 0.0 | 7 | 9.0 |
| Sub-total | 34 | 43.6 | 1 | 1.3 | 35 | 44.9 |
| Birds (no nest) | No. | % | No. | % | No. | % |
| Empty | 7 | 9.0 | 0 | 0.0 | 7 | 9.0 |
| Adult | 7 | 9.0 | 0 | 0.0 | 7 | 9.0 |
| Two adults | 2 | 2.6 | 0 | 0.0 | 2 | 2.6 |
| Adult and chick | 3 | 3.8 | 0 | 0.0 | 3 | 3.8 |
| Adult and egg | 17 | 21.8 | 1 | 1.3 | 18 | 23.1 |
| Adult and two eggs | 4 | 5.1 | 0 | 0.0 | 4 | 5.1 |
| Chick | 1 | 1.3 | 0 | 0.0 | 1 | 1.3 |
| Egg | 1 | 1.3 | 0 | 0.0 | 1 | 1.3 |
| Sub-total | 42 | 53.9 | 1 | 1.3 | 43 | 55.2 |
| TOTAL | 76 | 97.4 | 2 | 2.6 | 78 | 100.0 |

TABLE 3

Break down of Red-footed Booby cases (i.e. bird, nest or both) in December 1998, for habitats on Raine Island: Central Depression, North Section of the Southern Vegetated Ridge (NSVR); and South Section of the Southern Vegetated Ridge (SSVR).

| | Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Red-footed Booby | Depression | | NSVR | | SSVR | | TOTAL | |
| Birds (no nest) | No. | % | No. | % | No. | % | No. | % |
| Adult | 0 | 0.0 | 1 | 3.7 | 1 | 3.7 | 2 | 7.4 |
| Chick | 0 | 0.0 | 1 | 3.7 | 0 | 0.0 | 1 | 3.7 |
| Juvenile | 1 | 3.7 | 1 | 3.7 | 2 | 7.4 | 4 | 14.8 |
| Sub-Total | 1 | 3.7 | 3 | 11.1 | 3 | 11.1 | 7 | 25.9 |
| Nests | No. | % | No. | % | No. | % | No. | % |
| Nest | 0 | 0.0 | 6 | 22.2 | 14 | 51.9 | 20 | 74.1 |
| TOTAL | 1 | 3.7% | 9 | 33.3% | 17 | 63.0% | 27 | 100.0% |

associated with nests (29.5% of all cases). Other cases recorded were made up of empty nests (9% of all cases) with 34.6 per cent of all cases showing signs of breeding. Birds still incubating one or two eggs constituted 28.2 per cent of all cases (Table 2).

The census for all habitats combined resulted in 700 (± 15% se) Masked Booby nests, 570 (± 21% se) Masked Boobies and 1 270 (+ 12% se) cases. This compared with total counts of Masked Boobies, based on quadrat counts that included visible chicks but involved an unknown error factor, of 733 mid afternoon on 28 November 1998, and 888 mid morning on 10 December 1998. The number of Masked Boobies or their nests tended to be positively related to transect areas but this trend was not significant for those without nests (Pearson's Correlation (df = 7): birds 0.603, $p = 0.065$; nests 0.807, $p = 0.005$; all cases, 0.812, $p = 0.004$). The results were influenced by transect location ($\chi^2 = 41.612$, df = 8, $p < 0.001$, n = 78); the distribution of Masked Boobies and their nests being aggregated with 76 cases (97.4%) in the central depression and only two (2.6%) cases in the northern vegetated ridge.

*Red-footed Booby (Entire Island)*

In December 1998, the only signs of Red-footed Booby breeding in the sample transects other than nests, were one well-developed chick and four juveniles. Though there were only 20 nests in the sample area, the clumping of nests in the southern vegetated ridge on the western end of the island resulted in relatively large standard errors for the census estimates. In contrast with the other two species, no Red-footed Boobies were recorded on nests: all nests (74.1% of all cases) were empty. A single adult, chick or juvenile constituted the remainder of records involving birds (4) (Table 3). Given the small sample size, few conclusions can be drawn other than that in 1998 the breeding stage of the Red-footed Booby was further advanced than that of the other Booby species.

The Red-footed Booby census for all habitats combined resulted in 330 (± 43% se) nests, 110 (± 30% se) Red-footed Boobies, and 440 (± 35% se) cases. This compared with total counts of 30 Red-footed Boobies, including visible chicks but involving an unknown error factor, mid

afternoon on 28 November 1998, and 100 mid morning on 10 December 1998. Because there were so few birds, and because they nest in aggregations in the less sensitive areas of the island, a total count of Red-footed Boobies or their nests was feasible and therefore would be the preferred census method.

*Central depression comparison*

The estimate for the central depression in December 1998 was based on a sample area that constituted 6.56 per cent of the central depression. Because the area of the central depression in this study was determined to be 42 680 square metres, the Stoddart *et al.* (1981) densities of 0.06835 square metres (Brown) and 0.01730 square metres (Masked) were reworked accordingly. This resulted in estimates of 2 917 (previously 2 764 based on 40 440 $m^2$) and 738 (previously 699 based on 40 440 $m^2$) for Brown and Masked Boobies respectively.

The density for Brown Booby adults and juveniles in the central depression in December 1998 was 0.0139 square metres resulting in an estimate of 594 adults and juveniles; and for adults, juveniles and chicks the density was 0.0293 square metres resulting in an estimate of 1 249 Brown Boobies including chicks. The latter figure is approximately half that of the reworked Stoddart *et al.* (1981) estimate for November 1973.

Similarly, the density for Masked Booby adults (there were no juveniles) in December 1998 in the central depression was 0.0178 square metres resulting in an estimate of 761 adults. For adults and chicks the density was 0.0264 square metres resulting in an estimate of 1 127. The latter figure is approximately one and a half times that of the reworked Stoddart *et al.* (1981) estimate for November 1973.

## DISCUSSION

Because Stoddart *et al.* (1981) do not describe the nesting in the vegetated ridges it is not possible to ascertain whether there were fewer Brown Boobies on Raine Island in December 1998, or whether the perceived increase in Masked Boobies has resulted in more Brown Boobies nesting in other habitats. Few Masked Boobies were found outside the depression (Table 2). Although Stoddart *et al.* describe nest occupancy, they did not present proportions of occupied vs unoccupied nests so comparisons cannot be made.

Establishing the size of Booby populations on Raine Island proves difficult. Many birds leave the island early in the morning or roost on the beach during the day, returning to nests periodically during the day. Birds can be counted with minimal disturbance by viewing through a telescope from the tower on the eastern end of the island, but with no similar vantage points in western or central locations, undulations and central mounds block the view, again resulting in under-estimates. It was considered that establishing the breeding population by nest counts would be more reliable than daytime bird counts that are biased by absent birds.

In December 1998 the Boobies were relatively unaffected by turtle disturbance as the turtle numbers were extremely low with approximately 200–400 Green Turtles *Chelonia mydas* a night visiting the beach. Researcher disturbance to birds in 1998 was also minimal. No predation by gulls was observed. However, in 2000 when the first replication of the nest census was intended, it was abandoned because of severe predation of Booby eggs by Silver Gulls *Larus novaehollandia* associated with researcher disturbance of Boobies, thus exposing the limitations of this method.

Unfortunately the major problem of establishing reliable data collection methods for longitudinal analyses were not overcome by this exercise. It had been anticipated, after the success of this study in 1998, that the method described here would be useful for continuing studies. If the birds of the island are to be 'managed' data collected over time in consistent non-intrusive ways are essential, but the issue of how to achieve this effectively and efficiently is still unresolved.

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